Privatizing the Internet: Competing Visions and Chaotic Events, 1987–1995

Janet Abbate
Virginia Tech

The US National Science Foundation played a key role in the history of the Internet by overseeing its transition from government to private operation. In the process, NSF was forced to balance the competing visions of scientists, politicians, and private industry. This article describes the conflicts, trade-offs, and unexpected events that led to a technical and social transformation of the Internet.

> [T]here was nothing simple or conventional about privatization of the Internet. The reasons for doing it were complex. . . . It could be the Internet speaking in Walt Whitman's ''Song of Myself:''
>
> Do I contradict myself?
> Very well then I contradict myself,
> (I am large, I contain multitudes.)[1]

In the fall of 2007, 200 computer networking luminaries gathered in a hotel near the US National Science Foundation to celebrate the 20th anniversary of NSFnet. Speaker after speaker gave testimony to the effectiveness of the public-private collaboration that had transformed the military-academic Arpanet into a viable commercial service—a collaboration that conference organizers dubbed ''the partnership that changed the world.'' Then Bill Schrader, who had founded one of the first commercial ISPs, injected a note of harsh reality into the proceedings:

> Lest you go away with the misinterpretation that it was all about partnership and friendliness, I must tell you, that's not what I remember. . . . It was a series of battles. . . . The technology arguments were profound. . . . Talk about policy debates! . . . It was a series of very nasty, drag-out battles.[2]

Schrader's comment reveals an aspect of the Internet's evolution that has been largely overlooked by published histories, which tend to skip from the Arpanet to the World Wide Web with only a glance at the interim NSFnet period.[3] In fact, the NSF's brief stewardship of the Internet was a time when solutions to complex technical and organization challenges—most crucially, scaling up the technology and privatizing its management—were painfully hammered out, setting important precedents for today's commercial Internet.

Some historians see the Internet's privatization in the early 1990s as a logical, inevitable, and unproblematic step in its evolution, while others see it as an undemocratic takeover by a few powerful corporations to the detriment of the public good.[4] I argue, however, that characterizing NSF's actions as dominated by a privatization agenda would distort the motivations and expectations of those involved. Rather than being an overriding ideology, NSF saw commercial operation of the Internet as a means to an end: a robust, high-speed, economically sustainable information infrastructure for scientists. The questions then become, Why (and by whom) was privatization framed as the best or only means to this goal? What alternatives were considered, and how did events converge to support the particular form of privatization that occurred?

Three sociotechnical issues shaped the path of Internet privatization in important and unexpected ways. The first factor was expansion of the network's infrastructure, the user base, and the types of activities and applications supported. Rapid growth led NSFnet managers to approve unprecedented upgrades to the backbone's speed, but the cost and technical complexity of these upgrades put pressures on the network's informal management and financial

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structure. The second factor was the maneuvering of various actors within the NSFnet community to gain greater control over network operations. Although NSF managers approved some of these actions, other community members vehemently protested what they perceived to be power grabs that violated the spirit of the network and the public trust. The third factor was the emergence of data networking as a national policy issue. In 1986, the US Congress, led by Senator Al Gore, began debating a series of bills to fund a national network that would provide the advantages of the Internet to a much wider public. The bill's supporters voiced concerns about US technological and economic competitiveness as well as the need to spread Internet access to all Americans. Since the proposed network would build on NSFnet (and other government networks), the political debate complicated the management issues at NSF while also highlighting alternative paths to privatization.

This article examines how various actors framed the problem of expanding the Internet: what options they considered, what technical or economic goals they deemed possible, what pitfalls they wanted to avoid, and how they defined the public interest. I explain why finding a new model for operating the Internet was difficult and controversial, how and why they chose particular strategies, and how these choices shaped today's Internet.

Visions for the Internet, 1980s

In the early 1980s, the Internet was emerging at the intersection of several institutions, each with its own visions and priorities. Starting in 1969, DARPA had successfully built a wide-area packet-switched network, Arpanet, to serve its community of research contractors. Building on this, DARPA had developed techniques to join multiple networks into an interconnected network, or Internet, and in 1983, it had transitioned Arpanet to a new set of networking protocols (TCP/IP) that were specifically designed to connect diverse computers and networks.[5] Arpanet became the backbone, or main connecting network, of the emerging Internet.

Although the Arpanet had proven an extremely successful experiment, running an operational network was not part of DARPA's mission to pursue cutting-edge research. DARPA had two priorities with regard to the Internet: to find some other organization to take over Arpanet's operation and to promote the use of its TCP/IP suite. Implementing TCP/IP on various computer systems had been a huge collective effort on the part of DARPA's contractors, and it was by no means assured that other computer networks would follow suit. DARPA's support for the NSFnet effort—notably, permission to use the Arpanet as its first backbone—was in part a way to ensure that TCP/IP would become a widely used standard. As a nonproprietary standard, TCP/IP had some appeal in the commercial sector because it gave companies buying computers or network systems an alternative to the incompatible proprietary protocols computer vendors were offering. Thus, a privatized, commercially available Internet would present an attractive choice for many corporate users.

NSF had also been investing in networking. During the 1970s, NSF had funded small regional networks to link clusters of universities. From 1981 to 1985, it also supported a network for computer scientists called CSnet, which had used Arpanet for part of its infrastructure, providing a precedent for cooperation between ARPA and NSF. NSF's immediate motivation for building a network of its own was to connect the five supercomputer centers it was funding: the John von Neumann Center at Princeton, the San Diego Supercomputer Center, the National Center for Supercomputer Applications at the University of Illinois, the Cornell Theory Center, and the Pittsburgh Supercomputer Center.[6] In mid-1984, NSF created the Office of Advanced Scientific Computing to oversee the establishment of the supercomputer centers and, under the leadership of Dennis Jennings, to plan a high-speed network to link these centers with their users at universities across the country.

The first phase of NSFnet, starting in 1985, was a temporary setup that linked together the five supercomputer centers using 56 Kbps leased telecom lines and routers running the Fuzzball software created by David Mills of the University of Delaware.[7] Campus and regional networks connected to these five hubs either directly or through Arpanet. In November 1987, NSF awarded a five-year contract to build and operate the phase II backbone, which would use faster T1 (1.5 Mpbs) links and would serve the general research community, not just supercomputer users. The T1 backbone was operational from July 1988 to 1991. Connecting to the backbone were a set of regional networks, which in turn connected the local campus networks

that served end users. Some of the regional networks were the product of earlier NSF programs, while others were built specifically for the NSFnet.[8] The regional networks were important in connecting remote and resource-poor users to the NSFnet, and their operators tended to view the Internet as a public service where the drive for profit should not squeeze out less-advantaged users.

If a transition to a commercially provided network was NSF's ultimate goal, this vision was well hidden in early communications about the NSFnet. NSF did not hint at any intention to privatize the NSFnet when it promoted the network to its constituency of scientists in a February 1986 article in *Science*.[9] In addition to Jennings, the authors included W. Richards Adrion, deputy director of the Division of Computer Research at NSF, and the three academic computer scientists Lawrence Landweber, Ira Fuchs, and David Farber. Although it seemed clear to the authors that ''computer networks are required to link researchers to supercomputers and to each other,'' they acknowledged that many scientists were wary of the awkward and incompatible network systems then available: ''The scientist has been burdened with multiple access procedures, applications software interfaces, operating systems, and data formats.''[10] The article enticed scientists to believe that NSFnet was not simply a long-distance, high-speed data communications network but an easy-to-use, integrated system of hardware and software. For scientists who cared little about networking per se and simply wanted to get on with their research, applications with consistent, user-friendly interfaces were as important as the network itself:

> [NSFnet] has to provide both the network and the software tools and applications protocols to make the scientist's workstation an integral part of the larger networked environment. Our vision is of a network integrating the computer resources available and presenting these resources to the user as a single interactive system.[11]

It is striking, however, that virtually none of these user-interface features was actually provided by the NSFnet project. The vision of the Internet portrayed in *Science* was quickly abandoned. Rather than a specialized network tailored to the needs of scientists, the NSFnet would become a general-purpose network with minimal services that could be expanded to a much wider user base.

Likewise, the 1987 solicitation by NSF for management and operation of the NSFnet backbone expressed no interest in commercializing the network or even extending it to nonresearch users in the foreseeable future. According to the Program Objective, ''The long-term objective of NSFnet'' was simply ''to provide research communications among researchers and computer-related research resources.''[12] In fact, rather than specifying that government subsidies for the network would be phased out fairly quickly, as it had with CSnet, NSF anticipated that the NSFnet contract could be extended beyond the initial five years.[13] Looking backward from 1993, an NSF inspector general's report explained that

> We have been told by NSF staff that in 1986–87, when NSF conducted the NSFnet solicitation . . ., it was not clearly foreseeable when, or if, high-speed networking would become commercially viable. Therefore, NSF did not address the issue of commercial use of the network by the awardee in the solicitation or the Cooperative Agreement. Similarly, none of the offerors addressed commercial use in its proposal.[14]

The winner of the award to upgrade the NSFnet was an unusual public-private partnership led by Merit, a consortium of Michigan universities founded in 1966 to promote campus and state-wide networking. Merit served as project manager, provided engineering support, and ran the Network Operations Center. Merit's partners were the State of Michigan Strategic Fund (which offered $5 million), IBM (which supplied the packet switches), and MCI (which provided the circuits).[15] Each partner saw the network through the lens of its own interests; Michigan viewed networking as a way to grow the local economy in the face of industrial decline, while IBM and MCI saw the collaboration as a chance to develop packet-switching expertise and enter new markets for network hardware and services.

Stephen Wolff, who became director of the NSF Division of Networking and Communications Research and Infrastructure in 1986, praised the partners for their willingness to invest resources in the project. IBM and MCI contributed significant funds beyond what the agreement required, and engineers from all the participating groups worked day and night to solve technical problems and keep the network running.[16] This level of support took NSF's proposal

reviewers by surprise: ''the Panel was initially concerned because the proposed cost to the NSF was unrealistically low for the level of service promised. The Panel then noted the extraordinary degree of cost-sharing proposed.''[17]

Clearly, the Merit partners were planning to profit in other ways from their participation. In fact, competing players in the private sector feared that IBM and MCI would leverage their position as NSFnet operators to dominate the commercial networking business. This was a particular concern for the commercial Internet service providers that began to emerge in 1989 as spin-offs of the nonprofit regional networks. The ISPs had a vision of a commercial Internet market in which all providers could compete on a level playing field, but NSFnet's technical design created a monopoly at the backbone level—an arrangement that would soon cause strife within the community.

In the political realm, Al Gore was an early and outspoken proponent of the Internet in his roles as a US senator from Tennessee (1985–1993) and vice president (1993–2001). His leadership was crucial in getting funding and policy priority for the Internet, and he was a key (if misunderstood) figure behind its success.[18] Gore envisioned a national network that would support not only American researchers but also education. In promoting federal investment, he painted a scenario in which a rural schoolgirl could access the Library of Congress to research her report on dinosaurs, thus linking the Internet with issues of social equality.[19]

In 1986, Gore sponsored a bill charging the Office of Science and Technology Policy to conduct ''a study of the critical problems and current and future options regarding communications networks for research computers.''[20] The resulting 1987 report raised a new political issue: the threat of competition from Europe and Japan. OSTP warned, ''Other countries have recognized the value of national research networks, and following the early U.S. lead have developed and installed national networks. As a result, these countries are now much better prepared to exploit the new distributed collaborative computing than the U.S. is at the present time.''[21] At that time, the US was engaged in cutthroat competition with Japan for dominance in high technology, and in 1982, Japan had launched its Fifth Generation Computer Systems project, which aimed to leapfrog over the US with a combination of supercomputers and artificial intelligence.[22] This perceived threat increased congressional support for investments in what it called ''high performance computing,'' which came to include both supercomputers and networking.[23]

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US regulatory policy also significantly shaped the environment for NSFnet. The network was initiated under the Reagan administration, whose ideology favored privatization and deregulation. This same period also witnessed a major government intervention into the telecommunications industry in the form of the 1982 consent decree (effective 1984) that broke up AT&T. The resulting system of competing, interconnecting phone system providers would later be seen as a model for how the Internet's infrastructure could be provided by multiple private operators.[24]

Last but not least, the 1980s saw a surge in the number of computer users and network participants, thanks to the introduction of personal computers (most notably the IBM PC in 1981) and the popularity of powerful, affordable workstations that freed university researchers from dependence on the campus mainframe. Workstations were commonly connected by departmental or campus-wide Ethernets, while home computer users could access various dial-up commercial services. These trends created a large pool of potential Internet users, which contributed to the rapid network growth and fueled political visions of networking for all.

Thus, there were a multitude of independent actors in the 1980s with competing and evolving visions for the NSFnet and the larger Internet. Some saw the network as a public trust, others as an opportunity for profit; some wanted a testbed for high-performance technology, while others hoped for an economic driver and an edge in international competition. In the early 1990s, a series of technical, organizational, economic, and political events stemming from the rapid growth of the Internet would cause these groups to collide over the issue of privatization.

Toward Internet privatization

From a technical standpoint, the main issue in the early 1990s was congestion. Traffic on NSFnet soared after the Merit group upgraded the backbone to T1 speed, both because new networks and users were being added and because users were quick to take advantage of the increased capacity. The upgrade was completed in July 1988, and ''within a month, network traffic doubled on the NSFnet backbone. . . . [O]nce connected, scientists and researchers didn't know how they had ever gotten along without it. Their enthusiasm led to over 10% monthly increases in usage of the NSFnet backbone.''[25] The number of attached networks increased from approximately 300 in July 1988 to more than 5,000 in February 1992, while traffic grew over the same period from fewer than a million packets per month to 150 billion.[26]

In January 1989, the Merit partners proposed an upgrade of the backbone from T1 to the much faster T3 (45 Mpbs) speed. Federal networking policy was in favor of an eventual transition to T3, but this was generally projected to happen in the early-to-mid 1990s, and such an upgrade had not been part of Merit's original contract.[27] In 1989, NSF's own priority seemed to be adding new sites to the network, rather than increasing its speed, but the agency's reviewers decided it would be wise to do both in order to handle the unexpectedly rapid growth in network users and traffic.[28]

In May 1990, Merit's cooperative agreement with NSF was expanded to cover the new backbone.[29] The new T3 backbone, with 16 nodes, was built as a separate network running in parallel with the T1 backbone. The T3 backbone was completed in the fall of 1991, and traffic was gradually switched over.[30] Participants' accounts of the upgrade experience indicate that this decision led directly to privatization. The transition to T3 raised tremendous technical challenges in designing, building, and debugging switches that could handle packet-switching traffic at unprecedented speeds. As Merit chairman Doug Van Houweling recalled,

> The T1 network required that we build new packet switches, but the fundamental T1 data transmission technology was pretty solidly in place. What we didn't understand when we went to T3 was that we not only had to do the switches all over again, but we also had to learn how to transmit data over a full T3 line, which wasn't being done. So when we built the T3 network we had two technology frontiers to overcome, and they interacted with one another in all kinds of vicious ways.[30]

This provided the rationale for a privatization move by the Merit partners, who argued that the cost of developing the new technology would require both private-sector investment and business-oriented management. Al Weis of IBM recalled,

> No one had ever built a T3 network before; there were no commercial T3 routers available and telephone companies had little experience with clear-channel T3 lines. . . . I realized that if we were going to make this jump to 45 Mbps, ... you had to have an organization that was technically very strong and was run with the vigor of industry.[30]

While arguing that a transition to private management was a technical necessity, the Merit group also acknowledged the lure of profit from unmet commercial demand: ''non-academic organizations willing to pay commercial prices increasingly desired Internet connectivity, but were restricted from using the NSFnet backbone due to the NSF's Acceptable Use Policy.''[30]

The Acceptable Use Policy was a political and management issue that became increasingly thorny as the network grew and diversified. Because the backbone was government-subsidized, NSF forbade any commercial use of this infrastructure, limiting ''acceptable'' uses to academic and research activities.[31] Regional networks, however, were not barred from carrying purely commercial traffic and, in fact, were encouraged to do so by NSF's Wolff. Wolff felt that commercial traffic would improve the economics of the network: ''There had to be commercial activity to help support networking, to help build volume on the network. That would get the cost down for everybody, including the academic community.''[30] Wolff's ''strategy,'' as he later described it, was to use the AUP to force the development of private infrastructure: ''The predictable (and intended) result of encouraging commercial network traffic at the local and regional levels, while denying its access to national-scale transport, was the emergence and growth of 'private,' competitive, long-haul networks.''[32]

In Wolff's view, the AUP would safeguard the not-for-profit purity of the NSFnet

(as required by Congress) while spurring the separate development of commercial infrastructure to serve business users. However, when commercial firms were also involved in research, or when researchers wanted to access commercial services such as databases, it was not always easy to sort out ''acceptable'' and ''unacceptable'' network traffic. Wolff responded to this dilemma (and other politically imposed restrictions, such as limits on international connections) by quietly allowing benign but unsanctioned uses. Sometimes Wolff simply turned a blind eye to such activity; other times the activity was openly conducted as an ''experimental use'' that would enhance the net's research and educational use.[33] But these expedient workarounds were inadequate; some users felt that businesses were taking unfair advantage of the network, while some businesses felt that for legal reasons they needed explicit permission for commercial activity.[34]

For these technical and political reasons, most people in the Internet community believed that the network would eventually transition to private management. To open discussion on the topic, NSF and OSTP held a workshop in March 1990 at Harvard ''to explore the issues involved in the commercialization of the Internet.''[35] But few people expected to see a privately run Internet as soon as the early 1990s.[36] Government reports and legislation from 1989 to 1990 explicitly called for the eventual commercialization of the Internet, but this was not anticipated to happen until the late 1990s.[37]

It took the Internet community by surprise when, in June 1990, the Merit group proposed a new organizational and economic structure for NSFnet.[38] Merit informed NSF that it planned to create a nonprofit corporation called Advanced Network & Services, for which IBM and MCI would provide several million dollars in funding as well as personnel and equipment. Instead of Merit providing the NSFnet backbone service directly, Merit would subcontract those services to ANS. A major justification for this move was the corporate resources needed to implement T3—and IBM's Al Weis, who became president of ANS, was already urging a future upgrade to even faster gigabit speeds.[39] Wolff accepted the new arrangement in September 1990, arguing that it would increase investment in the backbone beyond what NSF could afford and would also solve the AUP problem by providing a way for commercial users to pay for NSFnet access. Any funds from business users were to be invested in infrastructure improvements and would not immediately profit ANS.

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ANS was only the first move by the Merit partners, which quickly followed with the next step toward privatization. In May 1991, ANS spun off a for-profit subsidiary called ANS CO+RE (for Commercial + Research and Education) Systems. CO+RE would use the same infrastructure as ANS to provide a purely commercial Internet service. Although Wolff might have welcomed these developments as a step toward a nonsubsidized Internet, he had evidently not considered the market implications of ANS/CO+RE's ad hoc privatization of the Internet backbone, nor the strong feelings of many users that the NSFnet represented a public trust.[40] The sudden appearance of CO+RE set off a firestorm of protest from Internet users and service providers who felt that Merit had rushed into privatization without consulting NSF or the community.[41] ANS/CO+RE seemed to have a conflict of interest in operating a nonprofit research and education backbone while simultaneously competing for commercial business with the networks it was supposed to be serving. The regional networks were upset because ANS wanted them to pay new connection fees and because CO+RE's commercial strategy included poaching customers from the regional networks or even supplanting them altogether.[42] Commercial ISPs objected to ANS having a monopoly over the NSF-funded infrastructure and demanded that NSF let them compete for the business of providing backbone services.[43]

Rejecting the costly and poorly defined fees that ANS proposed to charge regional networks for commercial traffic, three of the largest ISPs created their own system for free commercial interchange in February 1991. CERFnet, PSI, and UUNET agreed to interconnect their networks as the Commercial Internet Exchange (CIX) and to exchange all traffic for free. This would provide their

customers with coast-to-coast T1 connectivity and no AUP restrictions.[44]

A *Science* reporter blamed the controversy for driving NSF to give up its leading role in the Internet—though it seems clear that Wolff himself already wanted NSF to move away from direct network provision.[45] In further discussions with the Internet community, Wolff found a ''broad consensus'' that NSF should allow for several competing companies to provide backbone services.[46] In November 1991, NSF issued a new Project Development Plan that proposed awarding contracts to multiple, competing backbone providers—yet another vision that would soon be altered.

Meanwhile, Congress was proceeding with its own plans for the Internet, which politicians dubbed the National Research and Education Network. Congressional rhetoric justifying federal investment in the network initially stressed that US scientists needed high-speed connections for cutting-edge research, but the mandate gradually broadened to include K–12 education and libraries. In 1991, provisions for building the NREN were included in the *High-Performance Computing Act of 1991*.[23] The Gore Bill, as it was known, stressed the threat of foreign competition as its political rationale and reflected three beliefs: that high-speed (gigabit) networks were essential to research and as an economic driver, that industry would not provide such networks because the market and technology were not yet proven, and that government oversight was needed to ensure equitable access and proper network use.

Congress clearly did not anticipate any rapid privatization of the Internet infrastructure. Instead, the NREN was conceived as a joint public-private venture; while it would ''be developed by purchasing standard commercial transmission and network services from vendors whenever feasible,'' it would also ''be designed, developed, and operated in collaboration with potential users in government, industry, and research institutions and educational institutions.''[47] The issues being raised within the NSFnet community were still very much up in the air, as evidenced by the fact that the Gore Bill asked the OSTP director to report within one year on

- effective mechanisms for providing operating funds for the maintenance and use of the network, including user fees, industry support, and continued federal investment;
- the future operation and evolution of the network;
- how commercial information services providers could be charged for access to the network, and how network users could be charged for such commercial information services; and
- the technological feasibility of allowing commercial information service providers to use the network and other federally funded research networks.[48]

The new law reframed the NSFnet as an ''interim NREN'' and called on NSF to upgrade its backbone and regional networks and assist other agencies to connect to the network.[49]

The Gore Bill put NSF and Congress on a collision course. On the one hand, NSF was proceeding with privatization without the type of public participation and oversight that Congress felt was needed for such a transition. In addition, advocates for a government-funded NREN feared that rapid privatization of NSFnet would undermine the rationale for further government investment.[50] On the other hand, Congress was placing new responsibilities on NSF that complicated the agency's efforts to find a privatization strategy that its squabbling stakeholders would accept. Arguably, this additional burden hindered NSF from developing a more gradual and consensus-driven strategy for privatizing the backbone.

The plan NSF had drafted in November 1991 had leaned toward reopening competition for NSFnet backbone services, with awards to be made to multiple providers rather than just ANS. But the strategy that NSF came up with in May 1993, after extensive discussion and public debate, did not just restructure the NSFnet backbone—it eliminated it. Under the new plan, there would be no backbone contract at all. Instead, local and regional networks would buy backbone services directly from commercial ISPs. NSF would fund contractors to build four routers called *network access points*, and all participating ISPs would connect to one or more NAPs. This would allow traffic to be sent from one ISP to another, creating a unified Internet. A separate very-high-speed Backbone Network Service would be built to support scientific research, and this vBNS would be connected through the NAPs to the rest of the Internet.[51]

NSF solicited proposals for the new contracts in May 1993 and made awards in early 1994.[29] The four NAP operators were Bellcore/PacBell in San Francisco, Bellcore/Ameritech in Chicago, Sprint in New York, and Metropolitan Fiber Systems (MSF Datanet) in Washington, DC.[52] An additional contract was awarded to Merit and the University of Southern California's Information Science Institute to operate the routing arbiter, which managed the routing system for the whole network. MCI was awarded the contract for the vBNS, which it operated until 2003. After the new structure was put in place, the old NSFnet backbone was retired in April 1995.

The Merit partners benefited from privatization as they had hoped: IBM and MCI spun off commercial services, picking up many former NSFnet customers, and Merit remained on NSF's payroll as routing arbiter. IBM's routers laid the technical groundwork for a profitable new generation of personal computers and Internet routers, while MCI would become the largest carrier of Internet traffic.[53] The commercial ISPs, meanwhile, gained the chance to compete for customers without AUP restrictions, although their hopes for a level playing field would not necessarily be realized. Seventeen of NSF's regional networks were given short-term grants to help pay for commercial ISP service, but most of the nonprofit regionals were soon replaced by commercial ISPs. Most end users probably noticed little difference.

Those who feared that rapid privatization would erode political support for NREN turned out to be right. As *Science* noted when the plan was announced in 1993, ''This leaves the government's networking efforts at an awkward transition. . . . NREN was once supposed to lead to a national [gigabit] network, taking over from NSFnet in 1996.''[45] By 1993, however, Congress and the Clinton-Gore administration had replaced the vision of a federally funded research and education network with plans for a more general National Information Infrastructure. Internet connections were to be commercially provided, with government efforts focused on developing applications such as educational software, subsidizing access for libraries and schools, providing training for librarians and educators, and making government information available over the network.[54] Notable by its absence was any provision for public oversight of the Internet's expansion or operation. As historian Paul Ceruzzi has noted, ''Al Gore Jr. deserves credit for helping create the Internet, but the network he championed was not the Internet we know today.''[55]

The spread of the Web created new demand for Internet access among the general public just as commercial ISPs were positioning themselves to meet that demand.

Outcomes, choices, and lessons

What did privatization actually mean? It did not mean that NSF ''gave away'' a publicly owned system to private business. The backbone's communications links had always been leased from commercial providers, the regional and local networks that made up the bulk of the Internet did not change ownership, the TCP/IP protocols had been and remained nonproprietary, and control over routing and technical development stayed with nonprofit groups. Privatization was less a change in ownership than a change in who could serve NSF's users, how those users were subsidized (directly through grants, rather than through a subsidized infrastructure), and who made policy for the backbone.

Privatization brought many obvious benefits. The growing number of commercial ISPs proved able to handle the explosive Internet growth in the 1990s. Privatization eliminated the unworkable AUP, opened the way to competition among ISPs, and made it easier to integrate academic and industry users and to bring in the general public. The largely unregulated Internet was open to innovative new services, most notably the Web, which became easily accessible in the US through the free Netscape browser in 1994. Indeed, the spread of the Web created new demand for Internet access among the general public just as commercial ISPs were positioning themselves to meet that demand. This makes it difficult to separate privatization's benefits from those of the Web.

NSF's hasty path to privatization also raised troubling issues. Rajiv Shah and Jay Kesan's 2007 study spells out four problems resulting from the way NSFnet was privatized.[56] First, because NSF did not impose performance requirements on the NAP operators, the NAPs became congested and impeded backbone traffic flow.[57] Second, in the absence of a regulatory requirement for nondiscriminatory interconnection among ISPs, large backbone providers or private NAPs were able to exclude smaller players and thus undermine competition, increase concentration, and drive up prices. The lack of rules specifying universal unmetered interconnection led to an unequal two-tier backbone peering system, in which large ISPs agreed to exchange traffic for free but charged smaller ISPs for the same service.[58] Third, the lack of regulation means that unlike phone companies, backbone providers can, and sometimes do, harm subscribers by cutting off their connectivity on short notice.[59] Fourth, NSF did not require needed upgrades to network service, such as improved security. Other commentators raised a host of concerns ranging from technical to social and political.

The University of California, San Diego, computer scientist kc claffy, cofounder of the Cooperative Association for Internet Data Analysis, lamented that no provision had been made to keep Internet traffic statistics publicly available. Merit had provided this data as part of its agreement with NSF, but after privatization, ISPs began to withhold it as proprietary information or simply did not collect it at all. In 2006, claffy warned that this had created a crisis in network analysis:

> Metrics that are currently grounded in dangerously insubstantial measurement include the amounts and patterns of data traffic, the structure and evolution of Internet topology, the extent and locations of congestion, the amount or number of sources of spam, phishing, or DOS (denial of service) attacks, patterns and distribution of ISP interconnectivity, and other metrics that are critical to analyzing the security, stability, scalability, and sustainability of the Internet.[60]

Others predicted that the end of subsidies for the backbone and regional networks would create a digital divide as for-profit ISPs focused on the densest and most affluent regions. Legal activist Nathan Newman claimed,

The success of the privatized Internet should not blind us to the fact that trade-offs were made and other paths could have been followed.

> the earlier vision of cooperative regional networks promoting broad access to the Internet was increasingly giving way to a situation in which global multinationals were using control of regional chokeholds to serve elite customers and their own bottom line, mostly at the expense of the average citizen who paid for the Internet's creation in the first place.[61]

The media watchdog group Project Censored, which deemed the privatization of the Internet to be one of the ''Top 25 Censored Stories for 1996,'' argued that corporate ownership of the network would erode freedom of speech. Noting that US First Amendment protections do not apply to the private sector, they contended, ''What hasn't been discussed is the public's right to free speech in cyberspace. What is obvious is that speech in cyberspace will not be free if we allow big business to control every square inch of the Net.''[62]

Given the pressures facing NSF, what alternatives to its privatization strategy might have been available? One option would have been to keep the NSFnet under NSF management for a longer period and forego rapid growth.[63] However, the Merit partners' rhetoric stressing the threat of congestion and the need for gigabit speeds framed this option as undesirable or even impossible. A number of other options were considered at the 1990 Harvard workshop. For example, NSF could have turned over backbone operations to a nonprofit operator. Wolff even suggested ''privatization by function,'' in which commercially viable services such as mail and news would be blocked from the NSF backbone, while more specialized research applications would continue to use it.

Looking at the problem from the perspective of how to fund NSF's research users, there were also many alternatives, none of which stood out as clearly best:

> [T]he NSF subsidy that now underwrites the backbone could be moved down the distribution chain to the users of the backbone [in three different ways]—i.e., to the regional networks, to the campuses, or even to researchers themselves. . . . But the mechanisms for expressing user demand upward through these tiers are imperfect. And, from an administrative standpoint, it is easier for NSF to simply provide one free backbone to all comers—rather than deal with 25 mid-level networks, or 500 universities, or perhaps tens or hundreds of thousands of individual researchers.[37]

Thus, the particular path to privatization that NSF took was by no means the only possible choice. Given these uncertainties, NSF could have pursued privatization more gradually and used the extra time to gather public and stakeholder input on policy issues. Mitch Kapor, former president of Lotus and cofounder of the Electronic Frontier Foundation, suggested as much to ANS President Al Weis at a December 1990 network meeting:

> I have to say that it makes me nervous when these deliberations take place privately because I think the public interest is involved in this. I think it is commendable that you are aggressively trying to build the infrastructure, but I would really like to see public involvement on anything that is policy related. . . . It would be a tremendous mistake to pay any less attention to the policies than to the technologies.[39]

To Weis's comment, ''We have so much to do that we just can't afford to slow down,'' Kapor replied, ''But you also have the public trust. . . . Private enterprise is used to moving ahead in this expeditious fashion. But I'm suggesting that if you do this in your position, it will cause problems.''[39]

Could a privatized Internet have been placed under public oversight? Because NSF is not a regulatory body, any regulation of a commercialized Internet probably would have had to be done by the Federal Communications Commission (FCC), which would have been politically contentious. Using AT&T's breakup as a reference point, Fred Goldstein argued that a regulated network was not even considered:

> Unlike the telecommunications industry, . . . the Internet business . . . was deathly allergic to any kind of regulation. And how could it be regulated? Regulators take years to make decisions, yet the Internet was still like a child, growing and changing rapidly. Absent any dominance [by a single provider], there was no justification for economic regulation, be it telecom-style or antitrust.[64]

On the other hand, the concerns I have outlined here, as well as more recent debates over issues such as ''net neutrality,'' suggest that there might indeed have been some public and industry support for regulating ISPs.[65]

The success of the privatized Internet—its rapid growth, the abundance of new applications, and the continuing viability of noncommercial uses—should not blind us to the fact that trade-offs were made and other paths could have been followed. Perhaps the most important historical lesson is that virtually all the visions cherished by participants were abandoned or transformed. Scientists did not get a special-purpose, integrated computing system. Commercialization did not solve the congestion problem that had been a major rationale for privatization. The ''threat'' of Japanese computing invoked by Congress, as well as the promise of a federally created education network, have both been largely forgotten. Despite passing the baton to private industry, NSF still expends considerable funds on network infrastructure and connections.[66] Nevertheless, all these stakeholders benefited from applications, services, and uses that none of them had anticipated—and that little girl in Tennessee can finally research her report on dinosaurs.

References and notes

1. J.S. Quarterman, ''Revisionist Internet History,'' *S/W Expert,* May 1999, pp. 46, 49.
2. Presentations from ''NSFnet: The Partnership that Changed the World'' are archived at http://www.nsfnet-legacy.org/archive.php.
3. Doug Gale of the Internet History Archive made this same point at the NSFnet celebration: ''If you've looked at some of the popular histories about the Internet, one of the things that you'll notice is that there is a great deal of discussion about the ARPANET . . . and then there is suddenly a fast-forward to the World Wide Web'' (see http://www.nsfnet-legacy.org/archive.php). A recent notable exception is P.E. Ceruzzi's chapter on ''The Internet before Commercialization,'' *The Internet and American Business,* W. Aspray and P.E. Ceruzzi, eds, MIT Press, 2008,

which devotes 11 pages to NSFnet. Many histories were written while these events were still unfolding. For example, in *Computer: A History of the Information Machine* (Basic Books, 1996), M. Campbell-Kelly and W. Aspray, observe, ''As this book goes to press, the Internet is making the unsteady transition from public sector to private'' (p. 299). Ceruzzi's earlier *A History of Modern Computing* (MIT, 1998), which ends its narrative in 1995, is explicit that the commercialization of the Internet is beyond its scope (p. 296). S. Segaller's *Nerds 2.0.1: A Brief History of the Internet* (TV Books, 1998) discusses more recent events but skips over the NSFnet privatization entirely. My own book, *Inventing the Internet* (MIT Press, 1999), discusses the history of NSFnet at some length but does not attempt an in-depth analysis of privatization. As recently as 2007, R.C. Shah and J.P. Kesan, complained, ''Scholars have neglected the privatization of the Internet's backbone network, despite the obvious significance of the US government turning control of a powerful new communication technology over to the private sector'' (''The Privatization of the Internet's Backbone Network,'' *J. Broadcasting & Electronic Media,* Mar. 2007, p. 93). Their article critiques the privatization process but gives almost no consideration to the issues that led NSF to consider privatization in the first place.

4. The official NSF history, not surprisingly, is among those that depict privatization as necessary and good (S. Harris and A. Hansen, ''The Internet: Changing the Way We Communicate,'' *National Science Foundation: America's Investment in the Future,* 2000; http://www.nsf.gov/about/history/nsf0050/index.jsp). Other histories that see Internet privatization as inevitable include F.R. Goldstein's *The Great Telecom Meltdown* (Artech House, 2005) and S. Segaller's *Nerds 2.0.1: A Brief History of the Internet* (TV Books, 1998). Internet pioneers Robert Kahn and Vint Cerf paint Al Gore as a champion of much-needed privatization: ''As Vice President Gore promoted building the Internet both up and out, as well as releasing the Internet from the control of the government agencies that spawned it . . . Gore provided much-needed political support for the speedy privatization of the Internet when the time arrived for it to become a commercially-driven operation'' (R. Kahn and V. Cerf, ''Al Gore and the Internet,'' 28 Sept. 2000, http://www.politechbot.com/p- 01394.html). Critics of the privatization process include R.C. Shah and J.P. Kesan, ''The Privatization of the Internet's Backbone Network,'' *J. Broadcasting & Electronic Media,* Mar. 2007; G. Cook, ''NSFnet Privatization: Policy Making in a Public Interest Vacuum,'' *Internet Research,* vol. 3, no. 1, 1993, pp. 3–9; N. Newman, *Net Loss: Internet Prophets, Private Profits, and the Costs to Community,* Penn State Univ. Press, 2002.
5. J. Abbate, *Inventing the Internet,* ch. 4, MIT Press, 1999. Originally there was a single protocol, TCP, which was split into TCP and IP (transport and Internet protocol layers).
6. D.M. Jennings et al., ''Computer Networking for Scientists,'' *Science,* vol. 231, no. 474, 1986, pp. 943–950.
7. D.L. Mills, ''The Fuzzball,'' *Proc. ACM Special Interest Group on Data Comm. Symp.,* ACM Press, 1988, pp. 115–122.
8. These included BARRNet (in the San Francisco Bay area), MIDNet (in the midwest), NorthWestNet, NYSERNet (in the New York area), Sesquinet (in Texas), SURAnet (in the southeast), and WESTnet (in the Rocky Mountain region).
9. Jennings et al., ''Computer Networking for Scientists,'' pp. 943–950. Authors Landweber, Fuchs, and Farber were academic computer scientists, while Adrion was deputy director of the Division of Computer Research at NSF.
10. Both Farber and Jennings of NSF asserted at the NSFnet celebration that scientists had needed to be ''sold'' on the value of a network and that the *Science* article was an effective sales pitch.
11. Jennings et al., ''Computer Networking for Scientists,'' p. 950.
12. ''Project Solicitation for Management and Operation of the NSFnet Backbone Network,'' *NSF 87-37,* Nat'l Science Foundation, 15 Jun. 1987, p. 1.
13. NSF, ''Project Solicitation,'' p. 5.
14. ''Review of NSFnet,'' Office of Inspector General, NSF, 23 Mar. 1993, pp. 25–26.
15. E.M. Aupperle, ''Merit—Who, What, and Why. Part Two: The Middle Years, 1983-1993,'' *Library Hi Tech,* vol. 16, no. 1, 1998; http://www.merit.edu/about/history.
16. S. Wolff, ''NSFnet: The Partnership that Changed the World,'' http://www.nsfnet-legacy.org/archive.php. See also K.D. Frazer, ''NSFnet: A Partnership for High-Speed Networking. Final Report, 1987-1995,'' Merit, 1995, pp. 10, 24, 38–39.
17. ''Review of NSFnet,'' Office of Inspector General, p. 9.
18. See Kahn and Cerf, ''Al Gore and the Internet,'' which notes, ''No one in public life has been more intellectually engaged in helping to create the climate for a thriving Internet.'' Seth Finkelstein documents how the media distorted Gore's fairly straightforward claim in 1999,

''During my service in the United States Congress, I took the initiative in creating the Internet'' (http://www.sethf.com/gore/).

19. ''In his many articles and speeches touting the bill, Gore often used an example of a little girl, living in a rural area, at work on a school project. Was she information-poor due to her physical location, far from the resources of large cities? No—the National Research and Education Network would give her the capability to dial into the Library of Congress—to collect information on dinosaurs.'' J.A. Polly, ''NREN for All: Insurmountable Opportunity,'' *Library J.,* vol. 118, no. 2, 1993, pp. 38–41.
20. Public Law No. 99-383, *US Statutes at Large,* 1986; G.M. Vaudreuil, ''The Federal Research Internet Committee and the National Research Network,'' *ACM Special Interest Group on Data Comm. Computer Comm. Rev.,* vol. 18, no. 3, 1988, p. 6.
21. ''A Research and Development Strategy for High Performance Computing,'' Office of Science and Technology Policy, Nov. 1987, p. 18.
22. See J.M. Unger, *The Fifth Generation Fallacy,* Univ. Press, 1987. Japan's Fifth Generation effort is generally considered a failure because by the time its specialized systems had been created their capabilities were being matched by off-the-shelf hardware and software.
23. *High Performance Computing Act of 1991,* Public Law No. 102-94, *US Statutes at Large,* 1991.
24. For example, B. Kahin, argued that the breakup had shown that it was better to directly fund needy customers than to have a regulated system that subsidized all users (''Commercialization of the Internet: Summary Report,'' Internet Request for Comment 1192, Nov. 1990; http://www.faqs.org/rfcs/rfc1192.html).
25. Frazer, ''NSFnet,'' pp. 28, 29.
26. B. Chinoy and H.-W. Braun, ''The National Science Foundation Network,'' San Diego Supercomputer Center, 1992, p. 7; see also p. 8, Figures 5 and 6.
27. ''High Performance Computing and Networking for Science,'' background paper, OTA-BP-CIT-59. US Congress Office of Technology Assessment, Sept. 1989. p. 34.
28. ''Review of NSFnet,'' Office of Inspector General, p.12.
29. S.R. Harris and E. Gerich, ''Retiring the NSFnet Backbone Service: Chronicling the End of an Era,'' *ConneXions,* vol. 10, no. 4; http://www.merit.edu/networkresearch/projecthistory/nsfnet/nsfnet_article.php.
30. Frazer, ''NSFnet,'' pp. 30–32.
31. T. La Quey, *The Internet Companion: A Beginner's Guide to Global Networking,* Addison-Wesley, 1993.
32. B.M. Leiner et al., ''The Past and Future History of the Internet,'' *Comm. ACM,* vol. 40, no. 2, 1997, p. 105. This section of the article, presumably authored by Wolff himself, implies that he had adopted a ''privatization policy'' for NSFnet as early as 1986 (p. 105). Ceruzzi's ''The Internet before Commercialization'' notes that the AUP did force a transition to commercial ISPs, ''But the transition was awkward'' (p. 28). The 1992 Boucher Bill amended NSF's authorizing act to allow some commercial use of the network; Ceruzzi sees this as a key moment leading to privatization (pp. 29–30).
33. Wolff, ''NSFnet;'' Kahin, ''Commercialization of the Internet: Summary Report.''
34. J.Q.J., ''Re: Cygnus / Alternet dispute has settled down,'' 16 Oct. 1990, and J. Gilmore, ''I'm prepared to be told 'no','' 17 Oct. 1990, messages to com-priv mailing list; http://diswww.mit.edu/menelaus/com-priv.
35. Kahin, ''Commercialization of the Internet: Summary Report.'' This request for comments (RFC) ''attempts to synthesize the issues for the benefit of those not present at the workshop'' and was broadly circulated to the Internet community. Workshop participants included representatives from NSF, ARPA, OMB, OTA, Merit, the regional networks, the telecoms industry, university computer science departments, and think tanks.
36. For example, the 1993 Internet Companion states, ''It's going to take a while for commercialization and privatization of these networks to occur'' (LaQuey, *The Internet Companion*).
37. Kahin, ''Commercialization of the Internet: Summary Report.''
38. This move also skirted Merit's contractual requirement to get prior approval from NSF's Division of Grants and Contracts. See ''Review of NSFnet,'' Office of Inspector General, p. 46.
39. Cook, ''NSFnet Privatization: Policy Making in a Public Interest Vacuum,'' part 2.
40. The NSF Final Report acknowledged, ''The introduction of a new corporate structure to the NSFnet project . . . created controversy among members of the research and education community, as well as other members of the Internet community. . . . the NSFnet partners, including the NSF, found themselves in the midst of roiling debate.'' (Frazer, ''NSFnet,'' pp. 31–32).
41. The protest eventually led to an investigation by the NSF Office of Inspector General, which while it found no major wrongdoing, agreed that NSF should have sought peer review and/or public comment for this decision. The report complained, ''The record is utterly barren of documentation of NSF's reasoning for allowing commercial use of the network'' (p. 31).

42. Cook, ''NSFnet Privatization: Policy Making in a Public Interest Vacuum.''
43. Goldstein's *The Great Telecom Meltdown,* p. 65.
44. CIX was formally established as a trade association in Aug. 1991. Cook, ''NSFnet Privatization: Policy Making in a Public Interest Vacuum.''
45. C. Anderson, ''The Rocky Road to a Data Highway,'' *Science,* vol. 260, no. 5111, 1993, pp. 1064–1065.
46. S. Wolff, ''NSFnet Backbone services after November, 1992,'' message to com-priv and farnet mailing lists, 29 Nov. 1991; http://www.merit.edu/mail.archives/mjts/1991-11/msg00012.html. Wolff added, ''There is substantial agreement in the networking community that, while providing for continued Backbone services, the NSF should assure both that the incumbent is not favored and that there is an equitable opportunity for other firms to participate in the long-haul TCP/IP networking business.''
47. Public Law 102-94, section 102(c).
48. Public Law 102-94, section 102(g).
49. Public Law 102-94, section 201. NSF received an appropriation of $213 million for the first year of the program.
50. For example, Fred J. Howlett, the division manager for high-speed data networks at AT&T, told the *New York Times* in July 1990, ''The legislative momentum behind funding a high-speed computer network is strong right now. If there is any indication that corporations might go ahead without Government support, it wouldn't be helpful to the legislative effort.'' J. Markoff, ''Discussion Are Held On Fast Data Network,'' *New York Times,* 16 Jul. 1990.
51. Abbate's *Inventing the Internet,* ch. 6.
52. Frazer, ''NSFnet,'' p. 41.
53. Ceruzzi, ''The Internet before Commercialization,'' p. 24.
54. *High Performance Computing and High Speed Networking Applications Act of 1993,* H.R. 1757, section 2. This bill was never enacted into law.
55. Ceruzzi, ''The Internet before Commercialization,'' p. 31.
56. Shah and Kesan, ''The Privatization of the Internet's Backbone Network,'' pp. 100–104.
57. See also B.M. Frischmann, ''Privatization and Commercialization of the Internet Infrastructure: Rethinking Market Intervention into Government and Government Intervention into the Market,'' *Columbia Science and Technology Law Rev.,* vol. II, 2000–2001, pp. 49–52.
58. Goldstein's *The Great Telecom Meltdown,* p. 67; Newman's *Net Loss,* pp. 74–76.
59. Shah and Kesan, ''The Privatization of the Internet's Backbone Network,'' p. 103. They note, ''Former FCC Chairman Michael Powell acknowledged that although he could not stop backbone providers from shutting down their service, he could prevent phone service from being stopped.'' See also Newman's *Net Loss,* p. 78.
60. kc claffy, ''The Future of the Internet: Q&A with kc claffy,'' San Diego Supercomputer Center, 2006; http://www.sdsc.edu/profile/kcclaffy.html.
61. Newman's *Net Loss,* p. 77. Similarly, Frischmann argued, ''[E]ven if the market were to perform perfectly, it still would undersupply society with Internet interconnection infrastructure over the long-run because market demand for the Internet is only some fraction of social demand'' (''Privatization and Commercialization of the Internet Infrastructure,'' p. 69). Much literature exists on the ''digital divide'' in the US; for example, N. Dickard and D. Schneider, ''The Digital Divide: Where We Are Today,'' George Lucas Educational Foundation, 2002; http://www.edutopia.org/digital-divide-where-we-are-today.
62. ''Top 25 Censored Stories for 1996: Number 4, The Privatization of the Internet,'' Project Censored, 1996; http://www.projectcensored.org/top-stories/category/y-1996/.
63. Merit's Elise Gerich acknowledged that this would have been possible (though clearly not desirable, in her view): ''The network we could have built with only NSF's money would not have been as robust. It would have provided connections, but it wouldn't have had the same degree of redundancy'' (Frazer, ''NSFnet,'' p. 32).
64. Goldstein's *The Great Telecom Meltdown,* pp. 66–67.
65. For net neutrality see http://www.savetheinternet.com. See also *Internet Freedom Preservation Act of 2008,* H.R. 5353, 2008.
66. ''Fact Sheet: NSF and High-Performance Networking Infrastructure,'' Nat'l Science Foundation, 31 Dec. 2003; http://www.nsf.gov/news/news_summ.jsp?cntn_id=103049.

Janet Abbate is an assistant professor in the Department of Science and Technology in Society at Virginia Tech. She is the author of *Inventing the Internet* (MIT Press, 1999). She is currently writing a history of women in computing, and she guest edited the 2003 *Annals* special issue on this topic. Abbate has a PhD in american civilization from the University of Pennsylvania. Contact her at abbate@vt.edu.

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